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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 2000	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R-1 #2				
COST (In Millions)	FY 1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost To Complete	Total Cost
Total Program Element (PE) Cost	57.369	67.608	90.415	94.263	94.398	96.259	96.118	Continuing	Continuing
Information Sciences CCS-02	12.184	19.200	38.386	40.593	40.700	40.700	45.700	Continuing	Continuing
Electronic Sciences ES-01	19.662	21.761	17.498	19.743	22.645	30.506	36.365	Continuing	Continuing
Materials Sciences MS-01	25.523	26.647	34.531	33.927	31.053	25.053	14.053	Continuing	Continuing

**(U)      Mission Description:**

(U)      The Defense Research Sciences Program Element is budgeted in the Basic Research Budget Activity because it provides the technical foundation for long-term improvements through the discovery of new phenomena and the exploration of the potential of such phenomena for national security applications. It supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic and materials sciences.

(U)      The Information Sciences project supports basic scientific study and experimentation in information sciences technology areas such as computational models, new mechanisms for performing computation and communication integrating biological and information processes, innovative approaches to the composition of software, and novel human computer interface technologies. At the intersection of biology and information technology, this project will explore scientific study and experimentation emphasizing biological software, computations based on biological materials, physical interfaces between electronics and biology, and interactive biology.

(U)      The Electronic Sciences project explores and demonstrates electronic and optoelectronic devices, circuits and processing concepts that will provide: (1) new technical options for meeting the information gathering, transmission and processing required to maintain near-real time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near-real time; and (2) a substantial increase in performance and cost reduction of military systems providing these capabilities.

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(U) The Materials Sciences project is concerned with the development of: high power density/high energy density mobile and portable power sources; processing and design approaches for nanoscale and/or biomolecular materials and interfaces; medical pathogen countermeasures; materials and measurements for molecular-scale electronics; spin-dependent materials and devices; advanced thermoelectric materials for cooling and power generation; and novel propulsion concepts.

(U)	<b><u>Program Change Summary:</u></b> <i>(In Millions)</i>	<b><u>FY1999</u></b>	<b><u>FY 2000</u></b>	<b><u>FY 2001</u></b>
	Previous President's Budget	64.429	64.293	68.792
	Current Budget	57.369	67.608	90.415

(U) **Change Summary Explanation:**

FY 1999	Decrease reflects SBIR reprogramming and realignment of program priorities.
FY 2000	Increase reflects net effect of congressional adds for nanoelectric research and spectral hole burning and the government-wide rescission.
FY 2001	Increase reflects additional funding in Project CCS-02 for the Bio Futures program and expansion of molecular electronics, nanoscale/biomolecular materials and spin-dependent materials and devices efforts in Project MS-01.

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COST (In Millions)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Information Sciences CCS-02	12.184	19.200	38.386	40.593	40.700	40.700	45.700	Continuing	Continuing

**(U)      Mission Description:**

(U)      This project supports scientific study and experimentation that is the basis for more advanced knowledge and understanding in information sciences technology areas related to long-term national security requirements such as computational models and new mechanisms for performing computation and communication integrating biological and information processes. This project is also exploring innovative approaches to the composition of software and novel human computer interface technologies.

(U)      In the area of Bio Futures, the combination of biology with information technologies and physical systems will open a new field of incredible potential. These technical fields have reached a capability level where the combination can enable both fundamental and applications breakthroughs. Progress in biology will be greatly aided by the ability to understand and manipulate the massive data inherent in living systems. Microelectronics and sensors have reached the level of systems sophistication and miniaturization that they can directly interface with biological cells. The fields of biological science and technology offer an understanding of systems complexity and robust operation using fundamental unreliable components, understanding that will enable new approaches for information technology, computers, and electronics.

(U)      The Bio Futures effort will support scientific study and experimentation, emphasizing biological software, computation based on biological materials, physical interfaces between electronics and biology, and interactive biology. It will also apply information technology to accelerate the analysis and synthesis of biological processes by applying statistical language modeling tools to the problems of rapid bio-sequencing. The seamless integration of information technology and biological processes will provide the ability to exert computational control over biological and chemical processes and accelerated discovery of gene expression and protein-protein interactions. The Bio Futures program will also support the extraction of genetic circuit data from gene chips with the goal of determining the functioning of protein expression, protein interaction and cellular function. The applications of this will be to develop techniques using information theory for rational medical drug discovery and broad-spectrum antibiotics discovery for pathogens confronting the warfighter.

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(U) Advances in cognitive neuroscience make it possible for us to be able to interface biological systems with computer systems. In turn these will be used to develop new modalities of human computer interfaces including augmentation of memory and spatial reasoning capabilities. In the area of human computer interfaces the project will study information management, interface technologies and their relationship to cognitive processes.

(U) Ubiquitous Computing and Human Computer Interfaces will explore information technologies that are not in the domain of traditional information sciences, for example: creation of a new programming language suitable for teaching computer users, without previous programming experience; the fabrication of inorganic semiconductor transistors and logic units by printing; development of handheld communication and computer devices that users can interact with through speech and vision cueing without using standard keyboard entry. Ubiquitous Computing and Human Computer Interfaces will develop information technologies for an environment where we are surrounded by computers which interact with us in mobile, intuitive fashion and enable collaborations as well as intelligent exchange of information in a seamless fashion. Architectures for nomadic software, redesigns of classical notions of operating systems of computers, secure exchange of information over insecure channels are some of the technical challenges in this area. Database currency and management of dynamically changing world views is another important area of research in pervasive computing.

(U) **Program Accomplishments and Plans:**

(U) **FY 1999 Accomplishments:**

- Biological Computing. (\$ 4.242 Million)
  - Demonstrated and validated computing models, with emphasis on DNA-based logic operations and cell-based computation.
  - Investigated novel control mechanisms for self-organizing and autonomous systems.
- Human Computer Interfaces. (\$ 7.942 Million)
  - Demonstrated human-computer interaction for crisis planning.
  - Investigated feedback-driven approaches to information management.
  - Validated low-power configurable architecture; developed supporting software; and demonstrated automated mapping of 500K elements.

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(U) **FY 2000 Plans:**

- Biological and Amorphous Computing. (\$ 11.676 Million)
  - Evaluate alternative approaches to DNA-based computing and identify the most promising research opportunities for enhancement and acceleration.
  - Explore mechanisms for sequencing of DNA-based computations.
  - Investigate the use of game theory, probabilistic methods, and amorphous computing in Information Technology (IT), for use in decision aids and time critical systems.
  - Engineer complex artificial systems and explore biological systems across different size scales using multi-disciplinary approaches.
  - Explore biological inspired algorithms and models for computation.
  - Investigate novel approaches to real-time biological instrumentation in support of interactive biology, including development of minimally invasive imaging tools for monitoring the state of ongoing biological experiments.
- Ubiquitous Computing and Human Computer Interfaces. (\$ 7.524 Million)
  - Design and implement a prototype interactive programming environment for pervasive computing.
  - Develop architectural design for ubiquitous computing using mobile devices with multi-modal data entry.
  - Create a prototype Information Grid Room (IGR) that can provide invisible computing and data storage for a single user.

(U) **FY 2001 Plans:**

- BioFutures. (\$ 30.446 Million)

Biological and Amorphous Computing.

  - Demonstrate real-time multi-sensor imaging of cell processes in support of interactive biology.
  - Establish focused research initiatives at the interface between biology, engineering, and information sciences.
  - Demonstrate use of high resolution imaging technology and signal transduction to effect interactive control over simple biological systems.

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- Evaluate alternative approaches to the implementation of game theory, probabilistic methods, amorphous computing in decision tools and software development.

Bio:Info:Physical Systems Interface.

- Explore fault tolerant hardware architectures, software techniques with the ability to self-heal and reprogram adaptively.
- Demonstrate modeling and control of genetic circuits, expression of proteins, protein-protein interaction and cellular function for rational medical drug design.
- Develop new hybrid devices combining biological and artificial components scaling from molecular-scale to population level.
- Create biologically inspired algorithms and models for computation, possibly including systems of hybrid devices.
- Apply developments in biology, information science and materials science to dramatically improve the interactions of humans and systems.
- Explore elaborated Hidden Markov Model techniques for structural homology identification and sequence alignment in genetic circuits, and for protein expressions.
- Explore extraction-based data mining approach for discovery of intracellular protein interactions.

- Ubiquitous Computing. (\$ 7.940 Million)
  - Design universal software controlled communication interfaces that adapt to changes in the network and the surrounding environment.
  - Define the architecture for the interaction of multiple wireless handheld computers with speech and video input to enable the establishment of collaborative spaces and seamless transfer of information sources.
  - Upgrade Intelligent Grid Room (IGR) to support multiple users in distributed sites.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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COST (In Millions)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Electronic Sciences ES-01	19.662	21.761	17.498	19.743	22.645	30.506	36.365	Continuing	Continuing

(U) **Mission Description:**

(U) This project seeks to continue the phenomenal progress in microelectronics innovation that has characterized the last decades by exploring and demonstrating electronic and optoelectronic devices, circuits and processing concepts that will: 1) provide new technical options for meeting the information gathering, transmission and processing required to maintain near real-time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near real-time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities. Research areas include new electronic and optoelectronic device and circuit concepts, operation of devices at higher frequency and lower power, extension of diode laser operation to new wavelength ranges relevant to military missions, development of uncooled and novel infrared detector materials for night vision and other sensor applications, development of innovative optical and electronic technologies for interconnecting modules in high performance systems, research to realize field portable electronics with reduced power requirements and research addressing affordability and reliability. Additionally, electronically controlled microinstruments offer the possibility of nanometer-scale probing, sensing and manipulation for ultra-high density information storage “on-a-chip”, for nanometer-scale patterning, and for molecular level analysis and synthesis. These microinstruments for nanometer-scale mechanical, electrical and fluidic analysis offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

(U) This project is also concerned with coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components critical to enhancing the effectiveness of military platforms that enable warfighter capabilities for comprehensive awareness and precision engagement, and contribute to the continued advancement of Next Generation Internet capabilities. Topics to be researched include emitters, detectors, modulators and switches operating from infrared to ultra violet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules.

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(U) **Program Accomplishments and Plans:**

(U) **FY 1999 Accomplishments:**

- Infrared Detector Materials. (\$ 2.861 Million)
  - Established feasibility of new uncooled detector structures, including micro-machined arrays, thin film ferroelectrics and bolometric materials.
- Ultra-Electronics. (\$ 4.641 Million)
  - Demonstrated programmable matched filters operating at gigahertz speed with substantially less power than silicon complimentary metal oxide semiconductor.
  - Demonstrated completely integrated molecular beam epitaxy growth systems that realized closed-loop control of atomic layer growth and quantum device structures.
- Ultra-Photonics. (\$ 7.179 Million)
  - Identified the device properties limiting performance of vertical cavity lasers and demonstrated methods for controlling their output beam quality.
- Electro-Magnetic Interference Electronics. (\$ 1.928 Million)
  - Integrated promising new elements of ultraelectronics, high power electronics, non-volatile memory and Electro-Magnetic Interference (EMI) electronics.
  - Addressed, evaluated and applied current EMI thrusts in smaller, lighter, more mobile information systems and highest performance components and systems.
- Mechanical Electronics. (\$ 0.954 Million)
  - Initiated mechanical electronics development resulting in very high efficiency, low voltage Direct Current to Direct Current converters.

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- Terahertz Technology. (\$ 2.099 Million)
  - Explored technologies for a region of the electromagnetic spectrum (300 Ghz to 10 Thz, 1 mm to 30 micrometer) that has previously been difficult to access using conventional technologies, in order to exploit opportunities in environmental sensing, upper-atmosphere imagery and covert satellite communications.

**(U) FY 2000 Plans:**

- Mechanical Electronics. (\$ 1.888 Million)
  - Demonstrate the properties for mechanical switches that include device speed and current density scale and size, hysteretic behavior for non-volatile memory applications and reduction of threshold switching voltage to below 10V.
- Terahertz Technology. (\$ 3.397 Million)
  - Continue to exploit the terahertz region of the electromagnetic spectrum by investigating the best semiconductor approaches to sources and detectors, identifying mission critical operation.
  - Investigate the feasibility of integrating these components to form a range of compact subsystems for applications in space-based communications, remote sensing, covert communications, and chem-bio detection.
- Microinstruments. (\$ 10.809 Million)
  - Research new technology for diagnostic instruments to support, maintain and service the warfighter and military platforms.
  - Investigate new technology concepts that support high volume/low cost wearable and hand-held diagnostic instruments.
  - Explore microinstruments “on-a-chip” concepts that integrate sensors, electronics, storage, display and actuation.
  - Evaluate microinstruments that include fluid dispensing, fluid sensing, and fluid identification important for "in-the-field" medical, chemical/biological and equipment diagnostics and repair.
- University Opto-Centers. (\$ 5.667 Million)
  - Establish university opto-centers that are focused on creating new capabilities for the design, fabrication and demonstration of chip-scale modules which integrate photonic, electronic and Microelectromechanical Systems (MEMS) based technologies. Identify university technology research goals and modality for facilitating access by industry to these technologies.

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(U) **FY 2001 Plans:**

- Terahertz Technology. (\$ 3.772 Million)
  - Demonstrate, for the terahertz spectral region, the best semiconductor quantum-well approaches to sources, demonstrate semiconductor quantum-well detectors and identify system requirements to achieve space communications, upper-atmosphere imagery and close-operations covert communications.
- Microinstruments. (\$ 1.816 Million)
  - Demonstrate a patterning microinstrument that writes a pattern of array of 50nm minimum - feature-size bits or pixels at a rate of 6cm<sup>2</sup>/sec over an area of 1cm<sup>2</sup>.
- University Opto-Centers. (\$ 11.910 Million)
  - Demonstrate initial chip-scale integrated photonic, electronic and MEMS modules.
  - Identify the most compelling module DoD applications and measure level of industry commitment to adopt chip-scale integration approach.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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COST (In Millions)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Materials Sciences MS-01	25.523	26.647	34.531	33.927	31.053	25.053	14.053	Continuing	Continuing

(U) **Mission Description:**

(U) This project is concerned with fundamental research leading to the development of high power density/high energy density mobile and portable power sources; advanced thermoelectric materials for cooling and power generation; processing and design approaches for nanoscale and/or biomolecular materials and interfaces; materials and measurements for molecular-scale electronics; a new class of semiconductor electronics based on the spin degree of freedom of the electron, in addition to (or in place of) the charge; medical pathogen countermeasures; and novel methods for reducing drag in future generations of high-speed ships.

(U) **Program Accomplishments and Plans:**

(U) **FY 1999 Accomplishments:**

- Portable Power. (\$ 9.395 Million)
  - Optimized catalysts, membranes and separator plates for high energy density solid oxide and direct methanol fuel cells.
  - Conducted brassboard testing of compact, high performance 500W solid oxide fuel cells for portable power applications.
  - Demonstrated novel 500W thermophotovoltaic power sources based on advanced materials.
- Nanoscale/Biomolecular Materials. (\$ 6.306 Million)
  - Demonstrated the applicability of nanostructural materials in defense applications such as armor, high strength fibers, coatings and electronics.
  - Explored novel concepts in biomolecular materials and interfaces.
  - Developed single molecules and nanoparticles that exhibit electronic functionality and measured their intrinsic electronic properties.

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- Pathogen Countermeasures. (\$ 5.198 Million)
  - Determined mechanisms of disease causing (virulence) factors in pathogens of concern to the DoD.
- Thermoelectric Materials. (\$ 3.712 Million)
  - Developed thin film cooler utilizing quantum well structures.
- Advanced Drag Reduction (Fast Ship). (\$ 0.912 Million)
  - Conducted study to assess military utility and top-level system implications of high-speed heavy lift for future forces.
  - Conducted study to identify and assess different possible approaches for hydrodynamic drag reduction.

**(U) FY 2000 Plans:**

- Portable Power. (\$ 5.000 Million)
  - Design, build and test novel portable power sources that operate directly on logistics fuels.
  - Demonstrate a small (~50W) proton exchange membrane fuel cell operating on several novel hydrogen sources.
  - Demonstrate the operation of a portable direct methanol fuel cell.
- Nanoscale/Biomolecular Materials. (\$ 7.167 Million)
  - Explore novel processing schemes for the formation of nanoscale/biomolecular and spin-dependent materials, interfaces, and devices.
  - Explore the capabilities of quasicrystals, amorphous metals, meta-materials, carbon nanotubes, quantum dots, and other nanostructured/biomolecular materials for enhancing the structural and functional performance of defense systems.
- Molecular Electronics. (\$ 7.880 Million)
  - Demonstrate that molecules can be chemically tuned into a desired electronic functionality.
  - Fabricate nano-wires that are electrically conductive and can be assembled into rows or columns of wires via self-assembly.
  - Demonstrate that molecular and/or nanostructured materials can perform a storage function that can be driven from one state to another by an external signal.

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- Advanced Drag Reduction (Fast Ship). (\$ 3.000 Million)
  - Conduct integrated hydrodynamic model development at multiple scales to provide foundational theory for quantitative drag prediction and drag reduction prediction.
  - Commence laboratory-scale calibration and confirmation testing of initial model predictions.
- Nanoelectric Research. (\$ 1.900 Million)
  - Continue molecular and quantum-dot cellular automata nanoelectric research.
- Spectral Hole Burning. (\$ 1.700 Million)
  - Investigate the applications of spectral hole burning.

**(U) FY 2001 Plans:**

- Nanoscale/Biomolecular Materials. (\$ 10.000 Million)
  - Demonstrate enhanced performance from materials and processes incorporating nanostructured components.
  - Demonstrate the use of quantum chemistry for the theoretical design of new nanoscale/biomolecular/multifunctional materials and structures.
  - Explore the interface between biological systems and abiotic surfaces.
- Spin-Dependent Materials and Devices. (\$ 7.000 Million)
  - Demonstrate spin-polarized transport across ferromagnetic/semiconductor interfaces.
  - Optimize spin lifetime in semiconductor structures.
  - Demonstrate spin light emitting diode (spin-LED) and spin field effect transistor (spin-FET).

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- Molecular Electronics. (\$ 13.531 Million)
  - Demonstrate that molecules and/or nanoparticles can self-assemble into functional, regular patterns.
  - Build and test a minimum 16-bit functional, reversible molecular memory sub-unit.
  - Build and test room temperature scalable logic gates using molecules.
- Advanced Drag Reduction (Fast Ship). (\$ 4.000 Million)
  - Complete integrated hydrodynamic model development at multiple scales.
  - Complete laboratory-scale calibration and confirmation testing of initial model predictions.
  - Develop model-based performance predictions of different potential drag reduction techniques.
  - Commence laboratory-scale confirmation testing of drag reduction performance predictions.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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